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Viewpoint

A black-box approach on assessing the opportunity cost of deforestation

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ABSTRACT

The paper presents a new concept on assessing the opportunity cost of land use changes based on differentiating the ratio between the economic loss produced downstream by floods and the catchment area where different land uses eventually have different runoffs. Having the shares of different land uses and their corresponding runoff coefficients, the average loss per hectare within the watershed is further broken down according to the same land uses types and an average loss per hectare, for each type of land use, is finally appraised. Ceteris paribus, any further changes between different land uses, under the same rainfall regime, are assumed to produce different 'virtual' total losses, according to the degree to which high runoff land utilizations would have been changed in low runoff land utilizations or vice versa. The economic reasoning of the method is also presented in the broader context of the opportunity cost theory and a case study demonstrates the readiness of the method.

Introduction

Floods are quite common all over the world, being more or less associated with climate change (Kundzewicz et al., 2008; Milly et al., 2002); although they have been reported since bygone ages their frequencies are higher nowadays, being also correlated with deforestation processes (van Beukering et al., 2003; van Dijk et al., 2009). Therefore, the common sense wisdom says that planting new forests, or keeping the existing ones in upper catchment areas are cost-effective measures to prevent floods downstream provided that local communities living in the those areas are aware and acknowledge the important role played by the forests in flood mitigation. Being a matter of communication, some metrics are still needed to better explain the cause-effect relationships between land use (or land cover) changes, expected runoff, and floods that may occur downstream.

The correlation between land use changes and runoff have long been documented in literature (Crooks and Davies, 2001; Neris et al., in press; Rai and Sharma, 1998; Zhang et al., 2012), as well as the influence of forest cover on the runoff process, especially when large floods are common events (San Miguel-Ayanz et al., 2000; Sriwongsitanon and Taesombat, 2011; van Beukering et al., 2003; David et al., 2010; Niţă et al., 2011). In the broader context of climate change, Mander et al. (1998) analyzed the land use variations and their combined impact onto the runoff values, considering the warmer winters that typified the last four decades and the mean annual water discharges, while Bhuyan et al. (2002) tested and gauged, on a watershed located above a large reservoir in United States, a more complex model, able to predict the runoff and soil loss having known the land use and expected rainfall.

A meta-analysis carried out on the data provided by a large network of permanent plots produced quite accurate values for the soil annual loss, annual runoff and annual runoff coefficients, under different land uses, soil textures and rainfall (Maetens et al., 2012), which can be used to assess the impact of different land use changes across the Europe and Mediterranean area.

In Romania, an important synthesis of all forest hydrology studies was published in late seventies (Arghiriade, 1977). Quite recently the connection between forest land use and runoff was thoroughly explained in a study concerning the water retained by crowns, trees' bark, and litter in four watersheds under different rainfall intensities (Miţă and Mătreaţă, 2008). Kuemmerle et al. (2009) documented the land use changes produced between 1990 and 2005 In Romania with Landsat images, and the only significant alteration was reported for cropland, due to the high rate of abandonment on marginal lands. However, a study carried out on the Tisa watershed, based on similar satellite images taken at sub-catchments level, showed that the forest land use decreased between 1993 and 2001 with 10–20% (Dezso et al., 2005); this process, combined with heavy rainfalls brought about serious floods in the area.

Another aspect that needs further discussion are the runoff coefficients themselves: the method employed and the input data may produce different results, depending on how many criteria are used to differentiate the coefficients. Starting with a research paper

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Table 1
Surface distribution across land uses, slopes and soil texture in Suha watershed (hectares).

Land use	Soil texture	Slope category			
		<5%	6–10%	11–30%	>30%
Forest	Sandy	110.63	195.20	2769.17	5015.60
	Loamy	195.42	520.70	8745.72	8491.57
	Clayey	306.63	1.755	69.84	280.12
Pastureland	Sandy	51.56	70.68	475.15	513.38
	Loamy	37.78	95.85	2004.93	1672.77
	Clayey			11.21	11.68
Cropland	Sandy	412.29	211.89	257.69	159.75
	Loamy	499.44	604.81	1985.20	849.82
	Clayey	0	0	0	0

produced in 1997, which demonstrated the functional dependency between soil loss and the density of vegetation cover (Morgan et al., 1997) numerous studies were focused on this very narrow but important issue. As demonstrated, the connection between land cover and runoff depends to a great extent on the rainfall regime and soil moisture (Sriwongsitanon and Taesombat, 2011), which makes any flood prediction more difficult, especially when different slopes are considered (Martinez-Murîllo et al., 2013).

The rainfall regime influences runoff and erosion through multi-annual water discharges and average duration of floods, as demonstrated by a long-term study carried out in China (Fang et al., 2012; Peng and Wang, 2012). In Germany, a series of field experiments investigated the runoff differences between an old forest and a newly installed forest plantation and demonstrated that forest soils have a higher porosity and higher water conductivity rate beneath old stands of trees than beneath young plantation; consequently the surface runoff is smaller under mature forest than under newly established forest (Humann et al., 2011).

From a black-box perspective, a watershed is an area wherein the rainfall is the input while the outputs are the evapotranspiration, the water flow, the leakage to water table, and the accidental floods produced downstream. Simplifying more and changing the viewpoint, the loss produced downstream depends on the land use pattern, all other things (rainfall regime, leakage and evapotranspiration) being the same.

Materials and methods

Pilot area

Suha watershed, where the method was tested is located in the northern part of Romania, in the county of Suceava (see Fig. 1) and encompasses 36,322.31 ha. The forests (where Norway spruce is the main species) stretch over 70% of the total area, while the pastureland and agriculture land equally share the rest of the area. Typically for mountainous area, the pasturelands are to be sought on edges and plateaus, and cropland nearby settlements. The land uses, soils and slope distribution across the pilot area is presented in Table 1. The terrain configuration is pretty rugged, with steep slopes. Except for the small town of Frasin, the small hamlets of the two communes in the area are scattered along five valleys and are somewhat underdeveloped due to poor infrastructure; however their tourist potential is better and better managed since this small basin is crossed by a county road connecting two densely populated zones on both sides of the eastern chain of Carpathians.

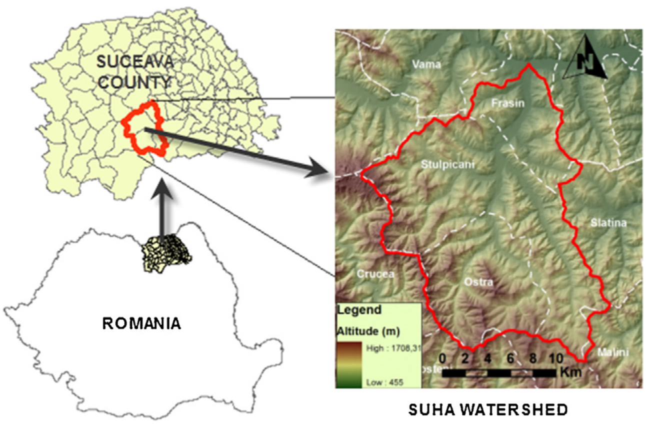

Fig. 1. Location of the Suha watershed.

The floods in the pilot watershed have been recorded since 1998 as well as the damages they produced. The total losses were assessed by the local authorities and further reported to the Inspectorate for Emergency Situations. All economic losses, expressed in Romanian currency, have been updated to July, 2012 prices and discounted at 6% per year, as shown in Table 2.

Main assumptions supporting the assessment method

In economics the opportunity cost is the revenue forgone when a factor of production is withheld or gets an alternative use (Price, 1991); it could also mean an avoided loss, as happened in case of healthcare programs (French et al., 2002) or avoided carbon emissions (Damnyag et al., 2011; Golub et al., 2009). The decision to change the forest use of land for a short period of time (i.e. clear cutting) or indefinitely (deforestation) has an opportunity cost, which means more floods, under the same rainfall regime.

Now, assuming that a hypothetical watershed, featuring the same slope and soil texture, had been used only for pastureland, the flood produced downstream would be homogenously generated throughout the whole catchment area, and the average loss per hectare would be the same. But in real situations, due to different land uses, slopes and soils textures, the terrain has different runoff coefficients and it makes sense to differentiate the average loss according to these coefficients, considering that a higher runoff, combined with a larger area, brings about 'more' flood. The loss breaking-down model developed in this study was inspired by the procedure employed by the Romanian National Forest Administration[1] to differentiate the average reserve price of stumpage into 800 different prices, corresponding to 16 species, five grades, five categories of hauling distances and two types of products (main yield and secondary yield).

[1] The main author of this article had implemented and improved this procedure between 1993 and 2001, when the stumpage market was completely liberalized. Before 2001 the National Forest Administration had been bargaining the stumpage price with timber industry representatives and the whole procedure, including the calculations behind, had to be supervised and approved by the Romanian Competition Council.